The effects of climate on welfare and well-being in Russia.[1]

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Abstract.

This paper measures the concepts of welfare and well-being in Russia on the basis of two large Russian household surveys, carried out in 1993 and 1994. Welfare refers to satisfaction with income and well-being refers to satisfaction with life as a whole. This paper investigates how climate conditions in various parts of Russia affect the cost of living and well-being. Climate equivalence scales have been constructed for both welfare and well-being.

1. Introduction

It is well-known that differences in climate affect the quality of life. Climate differences are informally recognised by multinationals and states extending over several geographic areas which supplement wages by climate allowances. However, little has been written on the impact of climate differences on well-being, a notable exception being the study by Blomquist, Berger and Hoehn (1988), who assessed the monetary value of amenities including some climate variables.

A second exception is the approach outlined in Van Praag (1988), which departed from data from a European survey in which respondents were asked to evaluate their own income level in terms of "good" and "bad". It was assumed that individuals who gave the same answer enjoyed an equal level of *welfare*. This allowed Van Praag to identify the monetary value to respondents of precipitation, humidity and

[1] *The Panel survey used in this article was held by the Institute for Comparative Social Research (CESSI) in Moscow under the guidance of dr. Anna Andreenkova. Funded by the European community, it was designed and commissioned by Prof. William Saris of the University of Amsterdam, whom we thank for allowing us to use the data-set.*

temperature. This approach has been refined further and is used here. We also apply the same methodology to another subjective measure, namely the satisfaction with life as a whole, which we call *well-being*, as developed by Cantril (1965). Thus we obtain and compare estimates of the effect of climate on both *welfare* (say satisfaction with income) and *well-being*.

After estimating the effects of climate on both welfare and well-being in Russia and computing the concomitant equivalence scales for various geographic sites, we then consider different scenarios for climate change and predict the subsequent increase or decrease in the climate costs for individual Russian households.

Section 2 explains the methods employed, whereby a subjective measure of financial welfare is used alongside a measure of general well-being. The main methodological innovation is that we take account of the fact that incomes at present already compensate for differences in climate, which changes the results substantially. We also discuss the differences between our methods and other popular methods for measuring climate costs, namely revealed preference methods and contingent valuation. Section 3 discusses the estimation results and section 4 compares the costs of climate at different sites. Section 5 calculates the probabilities of financial gain in the case of some climate changes. Section 6 concludes.

2. Methodology

We want to assess the monetary value of differences in climate across regions by measuring the amount of extra income respondents in one climate need in order to be equally well-off as respondents in another climate. By comparing individuals in different regions, we can estimate the influence of each different climate variable on welfare. More formally, let us say that welfare U is a function of two variables, current income y_c and climate C (or any other amenity). We have

$$U = U(y_c , C)$$

The monetary value of a climate change to an individual can be calculated by changing the climate conditions of an individual (by _c), and asking how much income would have to change (with _y) in order to keep welfare constant. This can be calculated as

$$0 = U_y \quad y + U_c \quad c$$

where the derivative of U to y is denoted by U_y and the derivative of U to C by U_c.
The shadow price of a climate change is now $\_y = - \quad c \times U_c / U_y$
If income itself depends on climate, which is frequently the case as companies and governments already partly compensate individuals for climate conditions, and if prices in a region (denoted by p_c) also depend on climate, for total compensation there has to hold that

$$0 = [\quad y + \quad c \times dy/dc] U_y + \quad c U_p \times dp_c/dc + \quad c U_c$$

which yields a shadow price of $\quad y = - \quad c \times [U_c/U_y + dy/dc + dp_c/dc \times U_p/U_y]$
For an empirical analysis we do not need to know the actual function U, but only the indifference surfaces (points where welfare is the same). This means that we have to

identify individuals who enjoy the same welfare level, in order to assess the shadow price of climate conditions for that welfare level. Herein lies the rub: how to identify persons at the same welfare level? Roback (1982, 1988) and Blomquist et al. (1988) circumvent this question by simply postulating that all households with identical wage-earning capacities are at the same welfare level, which in turn is based on the assumption of perfect mobility and the assumption that households have identical utility functions. As a result of these assumptions, differences in welfare cannot exist between regions as that would induce migration towards better-off regions. These assumptions are somewhat improbable for Russia where mobility is low. Another drawback of this method is that the shadow prices of climate found in Blomquist et al., and in more recent hedonic pricing studies such as Maddison and Bigano (1997), include both the pleasure costs of climate and the monetary costs of climate, but cannot distinguish between them. The empirical problem is that the monetary costs of climate include unobserved price differences in non-traded goods. Consider for instance the price of the non-traded commodity “feeling warm”. If an individual lives in a very cold climate, he will need to burn more fuel, will need more clothes and may need adapted transportation to stay warm. This will increase the price of staying warm. To find the real price of staying warm would need a very detailed and reliable set of prices and household expenditure data per region, which is not available. This makes it impossible to get at the monetary costs of climate in Russia via an analysis of the effect of climate on incomes and observed expenditures on marketed goods such as housing prices.

Another popular approach for measuring shadow prices, contingent valuation, avoids the problem of measuring welfare as well. Contingent valuation studies ask respondents how much they would be willing to pay for a particular change in circumstances, such as climate. People are simply asked to report the y which keeps them at the same welfare level: respondents are asked to solve for y

$$U(y,C)=U(y+\ y+\ c\times dy/dc,C+\ c)$$

The main assumption that has to be made for contingent valuation to work, assuming for the sake of simplicity that respondents try their best to answer the question honestly, which is often dubious (see Hanemann (1994) and Diamond and Hausman (1994)), is that respondents need to know what effect each possible climate change has upon their welfare.

Instead of using indirect methods to identify individuals at the same welfare level, we asked repondents directly about their present level of welfare, so that we could compute the shadow price of current climate circumstances by comparing individuals in different climates who gave the same answers. That is, we use a *subjective* utility concept. We shall look at two different concepts in detail, viz. *welfare* and *well-being*. The first stands for a narrow concept, say satisfaction derived from income or *monetary* welfare. The second concept is a much wider concept, it stands for satisfaction with life as a whole. The two concepts are each measured by a separate measurement instrument[2].

The first concept, introduced by Van Praag (1971), is operationalized using the *income-evaluation question* (IEQ). This is a question module in which the respondent is asked to qualify five household income levels[3]. The IEQ runs as follows:

> "Whilst keeping prices constant, what before-tax total monthly income would you consider for your family as: "

Roubles

very bad,...

bad, ...

not good not bad,...

good, ...

very good, ...

The five answers of individual i are denoted by c_{ij}. Their empirical log-mean and

[2] See Van Praag (1994) for an extensive discussion.

[3] Mostly six levels have been used and sometimes even nine or eight. In this Russian survey it was decided together with CESSI to use only five levels.

variance are:

$$m_i = \frac{1}{5} \bullet \sum_{j=1}^{5} \ln(c_{ij}) \qquad\qquad s_i^2 = \frac{1}{4} \bullet \sum_{j=1}^{5} (m_i - \ln(c_{ij}))^2$$

To enable us to use this attitude question for welfare comparisons, we make the crucial assumption that all households in a language community attach the same verbal label to the same welfare level. Van Praag (1991, 1994) researched whether it is in fact true that households attach the same meaning to verbal labels in a value free context: repondents were asked to translate verbal labels to a point on a line of fixed length. It turned out that there was a remarkable uniformity in the responses: not only did respondents use the whole line for their answers, they also displayed a tendency to use intervals of the same length between verbal labels. The exercise was repeated by asking respondents to translate the verbal labels to numbers on a (0,1) scale, with the same result of equal partition, i.e. $U_{\text{very bad}}$ » 1/10, U_{bad} » 3/10, etc. In that case, it is found that the verbal labels translated into numbers on a (0,1)-scale are well described by U_j=N((ln(c_j)-ì)/ó) (j=1,..,5), where N(.) is the standard normal distribution function. In this paper we shall consider ì as a want parameter and (ln(y)-ì) as an ordinal welfare index, as ó is taken to be a constant.[4]

So we only assume ordinal interpersonal welfare comparibility in the sense of Sen (1976), see also Parducci (1995).

The individual parameter ì has been shown to be well-explained by age, family size, family income and other personal variables (Van Praag (1971), Hagenaars (1986), Van Praag and Flik (1992)). More precisely, empirical relationships like

$$\mu_i(y_{ic}, fs_i, age_i) = \hat{a}_0 + \hat{a}_1 \ln(y_{ic}) + \hat{a}_2 \ln(fi_j) + \hat{a}_3 \ln(agi_j) + \hat{a}_4 \ln^2(age_i) + \hat{a}`C_i + \mathring{a}_i \qquad (1)$$

[4] *Previously it was found, and also confirmed for the data set used in this paper, that $ó_j^2$ is only weakly dependent on y_{ic}, fs_i, age_i or education; we shall therefore use the population average $ó^2$ for interpersonal comparisons (Van Praag (1971), Van Praag and Kapteyn (1973), Hagenaars (1986)).*

have been found to hold in each study, not only for Dutch data but also for data of many other countries and over time. In equation (1), y_{ic} denotes the current household income of respondent i, fs_i denotes the family size, age_i denotes the age of the respondent; ì$_i$(y_{ic},fs_i,age_i) is replaced by ì$_i$ or ì(y_i) whenever this is unlikely to lead to confusion. â`C stands for a linear combination of climate variables. å$_i$ ~ N(0,s^2) denotes the error term.

The welfare parameter ì$_i$ was found to depend on the current income of the individual i. It follows that individuals with different current incomes evaluate a specific income level differently. This phenomenon, embodied in â$_1$, is known as *preference drift* (called the "hedonic treadmill" by Brickman and Campbell (1971) in a more generalised context). It is an empirical operationalisation of the notion that welfare functions are evaluated relative to current circumstances within and outside of households (see Van der Stadt et al (1985)).

It follows then that we can estimate how welfare, understood as a function of the extent to which income meets financial needs, i.e., as a function of the welfare index ln(y_{ic})-ì$_{ic}$, varies with climate conditions. As ì depends on climate, we can calculate the amount of money needed to compensate households for different climate conditions. Such an equivalence scale is derived by comparing the income an individual needs to enjoy a specific welfare level in *one* set of circumstances to the income necessary for the same welfare level under a chosen set of *reference* circumstances. We describe the reference situation as (ln(y_{0c}), ì(ln(y_{0c}))). By equating welfare levels and solving for current income, y_{ic}, we get:

ln(y_{0c})- ì(y_{0c}) = ln(y_{ic})- ì(y_{ic})

which yields after substitution of ì by equation (1)

$$\ln\left(\frac{y_{ic}}{y_{0c}}\right)=\frac{b_2 \bullet \ln\left(\frac{fs_i}{fs_0}\right)+b_3 \bullet \ln\left(\frac{age_i}{age_0}\right)+b_4 \bullet \ln^2(age_i)-b_4 \bullet \ln^2(age_0)+b' \bullet (C_i-C_0)}{1-b_1}$$

(2)

We notice that this ratio or equivalence scale does not depend on the welfare level. Hence it is "independent of base" (see Blackorby and Donaldson (1991)).

Because this method yields an estimate of the amount of money needed to compensate for different conditions, we can interpret this equivalence scale as measuring the cost differences related to different conditions. This way of arriving at equivalence scales is called after the place where the method was first developed and is known as the *Leyden approach*.

Now we turn to our concept of *well-being*, which is much broader than the financial satisfaction concept defined above and is familiar from socio-psychological literature. It is a satisfaction-with-life question developed by Cantril (1965)[5]:

> "On a scale from 1 to 10, whereby 1 stands for very unsatisfied and 10 stands for perfectly satisfied, how would you rate your life as a whole?"

The answers obtained, denoted by V_i, are numbers on a (1, 10) scale. An equivalence scale can be calculated by comparing V - values or by comparing monotonic transformations of V values. Both methods yield the same equivalence scales. Hence we looked at the compensation needed in terms of money to keep somebody at a constant level of well-being in spite of a change in his other variables, e.g., *fs* or *age*, etc.. If climate variables have an effect on well-being as measured by the Cantril question, then we can also derive climate equivalence scales

[5] *Cantril's original question contained 11 vertical levels, from 0 to 10.*

with respect to well-being. Our first operationalisation of this method translates the Cantril-answers onto a (-,   ) scale. Increasing the similarity with the Leyden method, the variable V^*_i is defined as:

$$V^*_i = N^{-1}\left(\frac{-0.5 + V_i}{10};0;1\right)$$

We can now proceed by assuming that V* is generated by:

$$V^*_i = v_0 + v_1 \times \ln(y_{ic}) + v_2 \times \ln(fs_i) + v_3 \times \ln(age_i) + v_4 \times \ln^2(age_i) + v` \times C_i + å^*_i$$

where $å^*_i$ denotes the error term. An equivalence scale is constructed by holding the level V^*_0 of well-being constant and by compensating changes in climate conditions by changes in income. It yields a similar expression as in equation (2), albeit with different coefficients. For the structural part we get

$$V^*_i = V^*_0$$

which yields[6]

$$\ln\left(\frac{y_{ic}}{y_{0c}}\right) = \frac{n_2 \bullet \ln\left(\frac{fs_0}{fs_i}\right) + n_3 \bullet \ln\left(\frac{age_0}{age_i}\right) + n_4 \bullet \ln^2(age_0) - n_4 \bullet \ln^2(age_i) + n' \bullet (C_0 - C_i)}{n_1}$$

(3)

The resulting equivalence scale gives an estimate of the *money-equivalent* of the effect of different conditions on *well-being* and is called the Well-being-scale. It includes both the monetary costs of climate and the pleasure value of climate. Notice that the scale is again independent of base. An alternative way to derive equivalence scales from the Cantril-question assumes that the answers V_i are generated by an ordered probit equation. The results appear to be similar although less significant

[6] *This method of deriving equivalence scale was developed by Plug and van Praag (1995a) and Van Praag and Plug (1995).*

(see Table 3).

Expanding on the existing methodology, we considered the bias that our estimates would have if the incomes of respondents vary with climate conditions, as we know to be the case in Russia. To see how this can be remedied, consider what effect climate now has on income:

$$\ln(y_{ic}) = \text{è}_0 + \text{è¢}C_i + \text{è}_1\text{¢}X_i + \text{å}y_i \qquad (4)$$

where C stands for a vector of climate variables and X stands for the variables used for ì, and also education, 19 industry dummies and 12 dummies denoting several types of organisation, like farms, public organisations and private companies.

After estimating (4) for the climate variables used to estimate ì, we can calculate the full effect of climate upon welfare and well-being by deflating income for its climate specific component:

$$\ln(y_{\text{non-climate}}) = \ln(y_{ic}) - \text{è¢}C_i \qquad (5)$$

This measure of income was then used to correct household income for the way in which the labour market already compensates individuals for different climate conditions. The total effects of climate on welfare and well-being can be found by adding a term to the effects we find without a climate-corrected-income. Thus we can add $\text{â}_1\text{è¢}C_i$ to the estimated climate effects of ì and $v_1\text{è`}C_i$ to the climate effects of V^*_i.

Before turning to the empirical work, we will address the issue of precisely what climate costs we picked up and what climate costs we did not.

By looking at the amount of money households need to reach a given level of welfare, we are measuring the long-term costs induced by climate. This includes the effect of climate on the price of non-traded goods such as the price-increasing effect of cold on the price of "staying warm" via the increased need for heating or the price effect of climate on "health" via medical costs. The Leyden method also captures the effect of climate on the price of traded goods (e.g. the effect of rain on agricultural prices and housing prices). Thus, by indirectly looking at the effect of climate on total household needs, we measure in a reduced form all the costs of climate at once. As prices or levels of financial need may vary across regions for other than climatic reasons, such as through the effect of differences in political and economic systems upon prices and production capabilities[7], we add a limited number of regional dummies to pick up systematic non-climate differences between regions. Bias may also come in if respondents do not answer the IEQ correctly, i.e., if they have no firm idea as to what income they would need to realise a welfare level different to the present. The IEQ suffers from this problem to a lesser degree than other hypothetical questions such as used in contingent valuation for two reasons. Firstly, we do not ask that the respondent is *explicitly* aware of the effects of climate on welfare, nor that he attempts to give a money translation of climate changes. We only ask that he knows how much money he needs to reach a certain welfare level in his present circumstances. Secondly, we take direct account of the fact that welfare depends on the reference position (via the preference drift phenomenon). Similarly, the Cantril-question is not hypothetical in any way, it is merely rather volatile: evaluations of one's whole life are dependent on present mood and subject to random variations in interpretation so that many observations are needed to find the structural parameters. It is also possible that regional differences in culture and interpretation of the Cantril question would bias our results, although they were not picked up by the limited number of regional dummies we used (see appendix).

[7] *Note that things like differential unemployment rates or levels of development across regions should not have any effect on the level of financial need, bar the effect that is catered for by the inclusion of the effect of income on financial need.*

3. Data set and empirical analysis

This paper uses the first two waves of the Russian National Panel data set, that is the data of a panel of 3727 households who were interviewed in 1993 and 1994. After deletion of cases with missing values, 2508 observations of the first wave and 1904 observations of the second wave were aggregated[8].

As a first step, we will compare the results of the Leyden-method for the 1993/4 Russian data set with the results that were obtained and reported by Van Praag in 1988 for a large European data set collected in 1979[9]. In that analysis, no account was taken of climate effects on income.

In Table 1 we present the estimated coefficient values of the ì-equation for Western Europe 1979 and Russia 1993/4, suppressing the country-specific effects for non-climate variables and a 1994 intercept dummy for our Russian surveys.

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[8]Here we have taken the two waves as independent cases, as it was found that we can accept the hypothesis of equal coefficients in both waves and that the corresponding error terms in both waves were approximately independent. For more information, see the Appendix.

[9]The 1988 paper uses the EUROSTAT 1979 survey commissioned by the European Commission which was extensively discussed by Hagenaars (1986).

Table 1: Climate-ì regressions for 1979 and 1993/4*: the amount of income needed to reach a fixed welfare level under varying climatic circumstances

	Europe 1979	Russia 1993/4
Constant	6.94	2.17
	(20.6)	(2.1)
Family size	0.11	0.22
	(10.8)	(12.5)
Family income	0.57	0.65
	(57.0)	(60.2)
ln(TEMPERATURE)	-0.15	-0.72
	(5.0)	(4.7)
ln(HUMIDITY)	-0.41	0.32
	(6.8)	(1.2)
ln(PRECIPITATION)	-0.10	0.16
	(10.0)	(4.7)
	R^2=0.6584	R^2=0.7254
	N=13428	N=4412

*absolute t-values between parentheses. The European data set consists of surveys in the Netherlands, the United Kingdom, Denmark, France, Belgium, Italy, Germany and Ireland. TEMPERATURE is defined as the logarithm of the average temperature in a year for the European data set and equals the logarithm of average temperature plus 50 for the Russian data set. This difference in definition is unavoidable because of the colder climate in Russia and should only influence the size of the temperature coefficient, not its sign. It does mean that the actual effect of a temperature change differ much less than the coefficients would suggest. HUMIDITY is defined as the logarithm of the average humidity in a year. PRECIPITATION is the logarithm of the average annual precipitation. The Europe 1979 figures are borrowed from Van Praag (1988).

The differences between the relationship between climate and costs in Russia and Europe are reflected in Table 1 by the difference in the climate cost structure, the coefficients and the significance of the climate variables. Bearing in mind that a higher value of ì implies a lower standard of welfare when income is constant, it appears that higher temperatures are preferred in both areas, and that humidity does not increase the financial welfare of Russian households, contrary to the situation in Western Europe. The greatest difference is with regard to the effect of precipitation, which is generally seen as positive in Western Europe whereas in Russia a lack of precipitation does not entail higher costs but lower costs. This may well reflect the fact that in Russia, the lower average temperatures lead to lower levels of evaporation and hence a reduced need for precipitation. A lack of rain would thus be less of a problem in Russia than in Europe. Similarly, it may be the higher temperatures in Europe which lead to a preference for high levels of humidity ("wetness"). This suggest a set of interactions to be important.

It may thus be that there are more relevant aspects of climate not included in the earlier analysis. We have a whole list of variables for Russia, which were not available in Van Praag (1988). Moreover, there is more variation in climate in Russia than in western Europe[10].

Turning to the full analysis of climate costs in Russia in 1993/4, we have 13 different climate variables to work with, including the average temperature in January and July (JANTEMP and JULTEMP), the average annual temperature (TEMPAV), the difference between maximum and minimum temperature in one calendar year (TEMPDIF), the average level of annual precipitation (PREC), the average amount of precipitation in the summer and winter (SUMMERPREC and WINTERPREC), the number of raindays a year (RAINDAYS), the hours of sunshine a year (SUNHOURS), average wind speed a year (WIND), average wind speed in January (JANWIND) and the height of the region above sea level (HEIGHT). See the Appendix for the precise definition of the variables.

It can be expected that the effect of climate upon welfare and well-being is the result of several interactions. Some interaction terms therefore were also added. As we could distinguish only 35 different climate regions in the Russian 1994 data set, the number of climate variables included had to be restricted .

The only strong a priori expectation we had about the relationship between climate on the one hand and cost of living and well-being in Russia on the other is that we expected the extremely low temperatures to lead to a reduction in welfare and well-being. In the absence of other expectations, climate variables were selected on the basis of best fit: the model that explained the most variance was selected for both the Leyden concept and the Cantril concept. Then the wage-regression was run, for which the same variables were used as those selected for welfare, which turned out to fit reasonably well for wages. The full procedure is described in the Appendix.

[10] *Unfortunately, the 1979 data set is not available any more for further analysis.*

The results of the wage-regression are presented in Table 2 where we consider two versions, viz., a version with logarithmic age and education and a version with age and education in calender years. Given the differences in significance of the age-profiles, we prefer the logarithmic specification, although the difference in climate coefficients is very small. The estimation results for ì and Cantril are presented in Table 3.

Table 2: results of full climatic model-estimation for household wages*: expected household wages in different climate conditions.

	Least squares: Log-household income (1)		Log-household Income (2)	
Intercept	13.2	(4.3)	7.2	(2.4)
ln(# adults)	0.68	(28.9)	0.72	(23.2)
ln(age)	-3.41	(5.4)		
$\ln^2$(age)	0.47	(5.4)		
ln(education)	0.29	(12.0)		
age			-0.01	(2.8)
age^2			0.00007	(1.6)
education			0.04	(11.8)
Dummies:				
rural	-0.21	(7.4)	-0.2	(6.9)
Volga and South Russia	0.01	(0.2)	0.04	(1.0)
wave2	1.18	(39.7)	1.65	(44.7)
Climate variables:				
ln(JANTEMP)	-1.53	(2.9)	-1.32	(2.4)
ln(JULTEMP)	4.09	(4.2)	4.98	(3.9)
ln(TEMPDIF)	-2.62	(5.7)	-2.56	(5.4)
ln(JANWIND)	5.35	(4.7)	5.54	(4.7)
ln(HEIGHT)	0.04	(1.3)	0.05	(1.7)
Interaction Terms:				
ln(JANTEMP)*ln(JANWIND)	-1.54	(4.8)	-1.61	(4.9)
ln(PREC)*ln(TEMPAV)	0.002	(0.2)	0.003	(0.2)
R^2	0.577		0.579	
N	4127		4127	

*absolute t-values in parentheses. The 12 hidden organisation dummies include state, rented, stock company, joint venture, private company, self- or family employed, public firms and farms. The difference in the two specifications is whether or not age and education were entered linearly or logarithmical.

In the analysis of Table 2, education stands for the number of years completed. Comparing the climate block of Table 2 with that of Table 3, we see that the effect of climate on wages is roughly the same as the effect of climate on ì, suggesting that people are indeed already partially compensated for climate hardship. The smaller number of respondents included in the wage-regressions is due to a number of cases where education is missing.

Table 3: results of climatic model-estimation*: the effect of climate on the amount of income needed to reach a fixed standard of welfare (ì) and the effect of climate on overall well-being (Cantril).

	Least squares:				Ordered probit:	
	ì		Cantril		Cantril	
Intercept	-4.35	(2.0)	17.72	(5.3)	-	
ln(y)	0.62	(56.6)	0.25	(16.9)	0.14	(6.6)
ln(fs)	0.17	(8.7)	-		-	
ln(age)	2.14	(5.1)	-3.92	(6.6)	-2.69	(3.2)
$\ln^2$(age)	-0.30	(5.4)	0.53	(6.6)	0.36	(3.2)
Dummies:						
rural	-0.08	(4.3)	2.17	(4.7)	1.82	(2.8)
Volga and South Russia	0.13	(4.3)	0.08	(1.8)	0.08	(1.3)
wave2	0.36	(17.8)	-0.22	(7.9)	-0.17	(4.3)
Climate variables:						
ln(JANTEMP)	-1.30	(3.3)	-		-	
ln(JULTEMP)	3.84	(5.4)	-		-	
ln(TEMPDIF)	-2.31	(6.9)	-		-	
ln(JANWIND)	4.07	(4.9)	-5.67	(6.5)	-6.75	(5.6)
ln(HEIGHT)	0.11	(5.5)	-0.11	(3.4)	-0.08	(1.9)
ln(RAINDAYS)	-		0.86	(6.1)	0.36	(1.9)
ln(SUNHOURS)	-		0.84	(4.5)	0.37	(1.4)
ln(WINTERPREC)	-		-0.50	(4.3)	-0.16	(1.0)
ln(SUMMERPREC)	-		-0.35	(4.6)	-0.22	(2.1)
Interaction Terms:						
ln(JANTEMP)*ln(JANWIND)	-1.12	(4.8)	1.59	(6.7)	1.85	(5.7)
ln(PREC)*ln(TEMPAV)	0.06	(5.5)	0.21	(4.3)	0.09	(1.3)
ln(HUMIDITY)*ln(TEMPAV)	-		-1.45	(7.0)	-1.29	(4.4)
Rural*ln(PREC)	-		-0.34	(4.6)	-0.28	(2.7)
R^2	0.731		0.094			
McFaddens pseudo-R^2					0.007	
% of observations correctly predicted					55.8%	
N	4412		4412		4412	

*absolute t-values in parentheses. y denotes current household income not corrected for climate. For the total effect of climate on welfare and well-being, â$_1$è`C$_i$ must be added to ì and v$_1$è`C$_i$ to Cantril. Age stands for the age of the respondent. The percentage of observations correctly predicted denotes the percentage of Cantril observations which were correctly predicted by the ordered-probit model. It gives another measure for the success of the model as the pseudo-R^2, which is rather low.

We can be brief about the non-climate coefficients: regarding the ì-equation these results replicate the findings for other countries bar the unusually large coefficient for family size, which indicates that children have a larger negative influence on financial welfare in Russia than in most countries. This may reflect the recent increase in the relative cost of children in Russia. The non-climate Cantril coefficients indicate that well-being is positively influenced by income and declines with age until 40 after which it increases again.

Turning to the climate variables, a complicated picture emerges from Table 3. If we concentrate on climate and ì, we first see that the higher the temperature in January, the lower ì and thus the greater financial welfare, as expected. Another plausible relationship is that between JANWIND and JANTEMP, whose combination in the ì-equation can be read as:

$$4.07\times\ln(\mathrm{JANWIND})-1.12\times\ln(\mathrm{JANWIND})\times\ln(\mathrm{JANTEMP}) = \ln(\mathrm{JANWIND})\times(4.07-1.12\times\ln(\mathrm{JANTEMP}))$$

This implies that the negative effect of strong winds in January on financial welfare increases when January temperatures decrease, an effect we have called the "chill-factor". As for the effect of July temperatures and precipitation on ì, the presence of interaction variables and TEMPDIF which depend on the July temperature make it hard to interpret one without the others. To give an insight into the effect of these interacting variables, Table 4 shows whether the effect of an increase in temperature or precipitation results is equal to an increase or decrease in the income of the respondents. We calculate how much the change of a climate variable is worth in terms of percentage changes to the income of an individual. This is done by holding welfare and well-being constant while allowing the climate variable to change. Thus we find, using equations (2) and (3), the value of a change in climate.

Table 4: The effects of changes in temperature or precipitation on welfare and well-being: how much is a change in climate worth according to the welfare and well-being criteria?

	Welfare constant ä income	Well-being constant ä income
ä TEMPAV	3.0%	-15.6%
ä JULTEMP	8.2%	-20.7%
ä PREC	-0.1%	-1.0%

* This table calculates the average of the derivative for each individual in the data set of the full climate model, which incorporates a climate correction for income. Changes in temperatures are measured in Celsius whereas changes in precipitation are measured in millimetres a year.

A increase in the variable TEMPAV of one degree Celcius increases *welfare* on average just as much as an increase of 3% in income would do. However, an increase in the variable TEMPAV with one degree Celcius decreases *well-being* by the same amount as a decrease of 16% in income would.

We can see that despite the large positive coefficient of JULTEMP in Table 4, an increase in the July temperature actually increases household welfare and thus decreases ì. This is because of the effect of the increase in temperature in July on the average temperature, which in turn affects ì in various ways. Tables 3 and 4 show that, according to the welfare-criterium, welfare is greatest where the temperature in January is high, the temperature in July is high, at low altitude and with little rain.

A different picture emerges when we apply the well-being criterion: a cold and windy winter and high altitude were deemed negative for well-being, just as they were detrimental to financial welfare. Although not relevant to financial welfare, sunshine was evaluated as being positive whereas precipitation was on average evaluated as being slightly negative. Stickiness, high temperatures coupled with high humidity, reduced well-being without influencing welfare. Rural respondents were unhappier if rain increased.

From Table 3 and 4 we can see that the relationship between financial welfare and well-being is weak, reflecting the fact that financial welfare is only one of the components of well-being.

4. Climate equivalence scales

Using the results presented in Table 3, climate equivalence scales can be computed from equation (2) for any climate in Russia *which falls within the range of climates present in our data set*. Table 5 compares a variety of Russian climates by means of showing the climate equivalence scales for 6 different sites in Russia: Moscow in the centre of old Russia, Gurjew on the northern tip of the Capsian Sea, St. Petersburg near the Baltic Sea, Dudinka on the Arctic ocean, Novosibirsk in the Southern part of Siberia and Cholmsk in the extreme east of Russia near Japan. The equivalence scales are normalised to Moscow.

Table 5: climate equivalence scales in several Russian cities: relative incomes, the relative cost of living and the relative cost of well-being.

	Moscow	Gurjew	St. Petersb.	Dudinka	Novosib.	Cholmsk
Data						
JANTEMP	-9.9	-10.4	-7.6	-29.5	-19.0	-9.5
JULYTEMP	19.0	25.4	18.4	12.0	18.7	15.6
TEMPAV	4.5	7.8	4.6	-0.6	-0.2	3.1
TEMPDIF	28.9	35.8	26.0	41.5	37.7	25.1
JANWIND	5.0	6.3	3.4	6.7	4.1	6.8
WIND	5.0	5.5	3.6	6.4	3.8	5.7
RAINDAYS	187	83	196	189	197	199
PREC	568	164	559	267	425	777
HUMIDITY	76	67	77	79	75	75
SUNHOURS	1887	2579	1563	1518	2041	1604
HEIGHT156	23	4	20	162	29	
Equivalence Scales						
Current incomes	1.0	0.763	1.133	4.157	1.353	0.995
Leyden-equi	1.0	0.505	0.988	5.394	1.335	1.041
Well-being-equi	1.0	0.849	1.085	2.463	1.069	0.743

From Table 5 we see that climate has a strong influence both on financial welfare and well-being. In the climate conditions of Gurjew, income is about 24% lower than in a Moscow climate. in the climate conditions of Gurjew respondents only require about half the income needed in Moscow to maintain the same welfare level, which means that respondents in Gurjew are on average better off. The Cantril scale indicates that a 15% lower income would give responents in Gurjew the same well-being level as Muscovites. This means that at present, incomes in Gurjew are overcompensated for their climate if we proceed from a well-being criterium and undercompensated from a welfare point of view.

Not surprisingly, the most expensive of these six places to live is Dudinka, a very cold and windy area near the Arctic circle. The cheapest place to live according to the Leyden scale was Gurjew, a warm and dry place at low altitude with a relatively large number of sunhours.

Current incomes seem to concur more with what would be expected from the Leyden-scale than from the Cantril scale, suggesting that respondents are rather compensated for changes in welfare than for changes in well-being.

5. The effects of climate change

As a probe into the question of what the costs and benefits of climate change in Russia might be, we computed what would happen if the average temperature were to rise by one degree while all other climate variables remain unchanged[11]. If temperatures rose by one degree, inhabitants of Moscow would need 13.5% *less* income to maintain the same welfare level. Households in Moscow can thus expect to benefit from a rise in temperature. When we calculate the effect on each individual in our data set, we find that, in Russia, the average income impact of a 1 degree rise in temperature would also be a gain in income. The question is whether there would be an income gain if we look at the total effects of climate change. Ideally we would want to know what a changes in other climate variables in different regions would accompany a change in temperature. This would require causal relationships between temperature and other variables which are not yet known (Perman (1994)).[12] The problem is greatest when it comes to computing the

[11] Using equation (3), we could explicitly calculate the monetary benefits of climate changes for any individual or region in the data set. Given that we only had 35 different climate regions to work with however, we will only look at whether we can expect a gain or a loss.

[12] Some relationships are known and some are not. For example, high altitudes influence temperature negatively, but temperature does not influence altitude. The relationship between wind and temperature is not so clear-cut.

effect of climate change upon well-being. As Table 3 shows, well-being is generated by the interaction of highly correlated variables, whose cause-and-result structure is unknown. Model-based predictions do exist on the effect of a temperature rise on other climate variables, but the uncertainty of these predictions is to great to be reliable. The climate system is simply too unpredictable at present[13]. We have therefore restricted ourselves to an analysis of the effect of climate change upon financial welfare, since we can make reasonable assumptions on the variables involved.

One probable effect of higher temperatures is that they will be accompanied by more precipitation. An often quoted prediction by the Intergovernmental Panel on Climate Change (1990, 1995) is an increase in temperature of 2.5° Celsius coupled with an increase in precipitation of 8%. As these predictions about the extent to which temperature and precipitation will rise are still very rough, especially for individual regions, several different scenario's have been evaluated in Table 6. The effects of various changes in temperature and precipitation are explored by calculating the likelihood that the average Russian respondent would benefit financially from the climate change[14], i.e., that their ì would fall.

Table 6: likelihood of financial gain from climate change at constant welfare levels*: how likely is it that Russian households would in the long run on average gain from a change in climate?

Scenario:	Precipitation unchanged	Prec. up 5%	Prec. up 10%
Temperature up 1° Celsius	91%	87%	78%
Temperature up 2° Celsius	99%	99%	97%
Temperature up 3° Celsius	99%	99%	99%

* these probabilities were derived by calculating the standard estimates of the expected financial benefit for the average incomes in our data set. The formula is derived in the appendix. Estimates

[13] We would like to thank David Maddison and Richard Tol for pointing out the existence and limitations of the existing predictions.

[14] The assumption we make about the causal structure of climate is that in January wind remains unaffected by changes in temperature and precipitation. A change in average temperature is assumed to be a consistent change in the temperature throughout the year.

are rounded downwards.

From Table 6 we can see that if the climate coefficients of Table 3 do not change if the climate changes, Russian households will probably gain from increases in temperature.

It would be wrong to conclude from this table alone that Russia will benefit from climate change as the changes in costs that *households* currently incur from climate conditions are only a part of the costs incurred by climate change. Two effects of climate change on household costs which are not considered in this paper and which may tilt the balance against climate change are 1) transition costs, the costs of adapting to the new situation, and 2) the costs of indirect and as yet unknown effects, such as rising sea-levels.

7. Conclusions

The objective of this paper was to examine the effect of climate upon operational measurements of the concepts of financial welfare and well-being using a large Russian survey. Our findings are that climate has marked effects which differ substantially from the effects that the climates of Western-Europe have been found to have upon financial welfare in Western Europe. This is probably due to the greater range of climate in Russia. In Russia, financial welfare was found to be negatively related to cold and windy winters. Well-being is also influenced negatively by harsh winters, but benefits from the number of sunhours. The stickiness factor, high levels of humidity together with high temperatures, was also seen to have a strong negative influence on well-being.

The results were used to calculate the effects of climate change upon financial welfare, and it was found, not surprisingly, that, under strict assumptions, Russian households can in general expect to incur lower climate costs when the temperature rises.

Similar equivalence scales can be computed for other countries with greatly varying climates such as the USA. However, they might well give very different results from ours as the interaction between climate, cultures, soils, industrial practices, and agricultural practices, will lead to a distinct climate cost structure in each region.

The method employed in this paper only needs a household survey across many areas to calculating the costs of different climates. The same method can also be used to assess the money value of other conditions which affect the financial welfare and well-being of households, such as crime, health and public services.

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Appendix

This Appendix describes the way in which the climate variables were constructed, how the relevant climate variables were selected, how the effect of temperature changes was computed and how the two different waves of the panel were used.

A.1. Assignment of climate variables. The climate variables were computed using the average measurements of 104 different weather stations in the USSR for the period between 1931 and 1960 (Müller (1983)). Each of the 113 sampling points was assigned to the nearest weather station. If the distance to the nearest weather station was greater than 1/3 of the distance to the second nearest weather station in a different direction (at least 100 degrees angle), the climate variables were obtained by distance-weighted linear interpolation. This whole procedure transformed the 113 sampling points into 35 different climate regions.
As the temperature in January was often negative, it was increased by 50°C. In order to keep the temperature variables consistent, all temperature variables were increased by 50 degrees. As large regions of Russia are below sea-level, HEIGHT was also increased by 50 meters. The difference in temperature between January and July was named TEMPDIF. All variables were then transformed by taking logarithms. The climate variables are thus defined from the raw variables, such as those in Table 5:

JANTEMP	= Average maximum day temperature in January in Celsius + 50
JULTEMP	= Average maximum day temperature in July in Celsius + 50
TEMPAV	= Average maximum day temperature in a year in Celsius + 50
TEMPDIF	= JULTEMP-JANTEMP
RAINDAYS	= the average number of days on which precipitation exceeded 0.1 mm.
HEIGHT	= (height in meters above sea level + 50)/100
PREC	= average annual precipitation in mm.
JANWIND	= average wind in January in m/s
HUMIDITY	= relative humidity in percentages
SUNHOURS	= average number of sunhours in a year
WINTERPREC	= average precipitation from October 1 to April 1
SUMMERPREC	= average precipitation from April 1 to October 1

As this study only distinguishes 35 different climate areas, there was a distinct danger that our climate

variables were correlated with other regional phenomena, such as differences in life-styles and agricultural practices. To counter this, our analysis first included variables denoting four big areas in Russia. Only the region of Southern Russia+Volga was significant and a dummy for it was retained in all analyses. Sampling point were assigned a rural status if they represented a village, a group of villages or a group of farms.
Although the 1988 sample distinguished 90 different climate regions, the present study has the advantage of containing more extreme climate conditions than the 1988 sample, which had a collection of temperate zones in Europe as its base.

2. Selection. After recoding, several factor analyses were run. The first two principle factors explained 75% of the variance amongst the component variables, JANTEMP, JULTEMP, RAINDAYS, RURAL, HEIGHT, WIND, TEMPDIF, PREC, TEMPAV, JANWIND, HUM, and SUNHOURS.
These two factors were then included in the ì-equation and in the ordered-probit of the Cantril-equation, while all other climate variables were omitted. Although the factors were quite significant, inclusion of the climate variables separately explained significantly more variance than the factors on their own. This also held when four factors were retained. Adding this to the fact that Kaizer's (1974) measure of sampling adequacy was very poor (0.567), factor analysis was disgarded for determining equivalence scales.
Expecting that climate costs were the result of a complicated interplay between climate variables, several interaction terms were created. First of all the chill factor: ln(JANTEMP)×ln(JANWIND). Second the stickiness factor: ln(TEMPAV)×ln(HUMIDITY). Some other interaction terms were tried: ln(TEMPAV)×ln(PREC), Rural×ln(TEMPAV), Rural×ln(PREC), ln(JANTEMP)×ln(WINTERPREC), ln(JULTEMP)×ln(SUMMERPREC), ln(TEMPDIF)×ln(PREC).
Since there was no strong a priori reason for selecting a particular group of variables, a best-fit method was pursued. The selection of the variables followed the principle of maximum R^2 improvement, this being the adding and deleting of variables until the best fit at each number of regressors is found and stopping when the adjusted R^2 no longer increases.
The same procedure was followed for the Cantril-variable. The R^2 for the model chosen was almost identical to the R^2 of the model with all variables (difference<0.001). The variables selected for the continuous Cantril model were then automatically selected for the ordered-probit Cantril model in order to keep the results comparable. The results of this procedure are shown in Table 3. To check whether different respondents interpreted the Cantril question in the same way, we performed the analysis separately for several education, age, and gender groups (with the same climate variables). No significant difference was found for the relative values of the different intercept terms, and no qualitative difference (sign and magnitude were similar though the nil-hypothesis of equality of coefficients was rejected) was found for the variables of income and climate, suggesting that different groups of respondents do interpret the question roughly in the same way.
Wage-regressions were run and as the variables used for financial welfare fitted the wage-regression well, they are shown in Table 2.

3. In Tables 4 and 6 an increase in January or July temperature is translated into half that increase for the average yearly temperature. If TEMPAV is increased by 1 degree, it is assumed that the temperature throughout the year has risen by 1 degree. Precipitation increases are also assumed to be reflected with equal precipitation-increases throughout the year. Wind is assumed not to be related to temperature or precipitation.
To derive the probabilities in Table 6, we first compute the income gain of a change in climate for each individual. Using equation (2) for equivalence scales this gives us an expected income gain per person and a standard deviation of that estimate. By averaging the expected gain and its standard deviation over all individuals, we obtain both an estimate of the average gain and of the standard estimate of the average gain. This yields the probabilities in Table 6.
In formulas: by applying the approximation theorem on functions of normally distributed vectors (proved for instance in Serfling (1981) as theorem 3.3.A.), we get (â` represents the coefficients of the relevant climate vector, C_{ti} represents climate vector C at time t for individual i, S represents the covariance matrix of the relevant climate variables, whereby t=0 refers to the situation without climate change and t=1 refers to the changed climate conditions) for the individual expected gain:

$$e^{\frac{b'(C_{0i}-C_{1i})}{1-b_1}} \sim N\left(e^{\frac{b'(C_{0i}-C_{1i})}{1-b_1}}, \frac{(C_{0i}-C_{1i})'\Sigma(C_{0i}-C_{1i})}{(1-b_1)^2} e^{\frac{2b'(C_{0i}-C_{1i})}{1-b_1}}\right)$$

which denotes the distribution of the income gain of a climate change for an individual and

$$\frac{1}{N}\sum_{i=1}^{N} e^{\frac{b'(C_{0i}-C_{1i})}{1-b_1}} - N\Big(\frac{1}{N}\sum_{i=1}^{N} e^{\frac{b'(C_{0i}-C_{1i})}{1-b_1}},\ \frac{1}{N^2}\sum_{i=1}^{N}\frac{(C_{0i}-C_{1i})'\Sigma(C_{0i}-C_{1i})}{(1-b_1)^2}\, e^{\frac{2b'(C_{0i}-C_{1i})}{1-b_1}}\Big)$$

which denotes the distribution of the average gain for the sample of a climate change.

4. Panel data. The first two waves of the Russian panel were lumped together in order to perform this analysis (two observations from one person counted as two observations from two different persons). To see whether this pooling was allowed, we tested whether, apart from the intercept term, the coefficients of the variables had changed significantly from 1993 to 1994 using a Chow-statistic. The independence was accepted at the 5% significance level. Thus there was no fundamental shift in the coefficients of variables between the two waves. In order to see whether the residuals were correlated, the residuals of the first wave ì-equation were regressed on the residuals of the second wave after the coefficients of both waves had been estimated separately. The explained variance was very low (R^2=0.04) and the correlation coefficient was about 0.12. The same correlation coefficients were found if we estimated the models under the assumptions that all coefficients were identical between the two waves. We thus concluded that analysing the waves separately would add very little information and that lumping them together would not distort the results. As a check, the analysis for Table 3 was also performed using only one observation per household, whereby the second wave observation was only selected if the first wave observation contained missing values. The resulting analysis (N=3011) did not alter any of the coefficients of Table 3 by more than 5%. See the Appendix of Frijters and Van Praag (1995) for further information on the measurement of income and other variables.